





Meeting of the Parties to the Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes

Working Group on Water and Health

Tenth meeting Geneva, 15 and 16 November 2017 Item 7b of the provisional agenda Informal document 4 **Drinking-water quality surveillance**

INFORMAL DOCUMENT

A risk-based approach towards strengthening drinking-water quality surveillance - First draft for comment by the Working Group on Water and Health -

The Protocol on Water and Health emphasizes the need to establish and maintain legal and institutional frameworks for monitoring and enforcing standards for the quality of drinking-water and promote the operation of effective networks to monitor and assess the provision and quality of water-related services.

Drinking-water quality surveillance is a thematic priority area under the Protocol's 2017-2019 programme of work, co-led by Belarus and Norway. The development of a document to promote a risk-based approach in drinking-water quality surveillance has been identified as one of the main activities under this thematic area.

The ninth meeting of the Working Group on Water and Health (Geneva, 29 -30 June 2016) provided feedback on an annotated outline prepared by the lead Parties and the WHO/Europe secretariat. The first meeting of the Expert Group on water quality surveillance (Minsk, 13-14 February 2017) reviewed and provided conceptual technical inputs on the scope, key principles and structure of the document. Consequently, the first draft has been prepared for review for the tenth meeting of the Working Group on Water and Health and the Expert Group.

The Working Group on Water and Health is requested to review the draft document and provide feedback on the following:

- List of key principles and their description
- Format of the document
- Provide suitable case study for relevant principle.

Note: Please submit comments and feedback to Enkhtsetseg Shinee (enkhtsetsegs@who.int) by 20 December 2017.

Risk-based approaches towards strengthening drinking water quality surveillance (first draft)

Developed by	Date	Version	Comments
SP and KP	08/11/17	1	First draft for comment
			on the relevance and
			content of the
			principles.

Abstract

Acknowledgements

Executive summary (short summary of the core principles and key messages for policy makers)

Contents

Introduction

The Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Water Courses and International Lakes, has the objective (Article 1) '...to protect human health and wellbeing, both individual and collective, within a framework of sustainable development, through improving water management, including the protection of water ecosystems, and by preventing, controlling and reducing water-related diseases'. The Protocol is the first international agreement of its kind adopted specifically to attain an adequate supply of safe drinking water and adequate sanitation for everyone, and effectively protect water used as a source of drinking water¹.

The Protocol on Water and Health makes several links to drinking-water quality surveillance:

- In accordance with Article 6 Paragraph 2 (a), the Parties shall establish targets for the standards and levels of performance that need to be achieved or maintained for a high level of protection against water-related disease, including on the quality of drinking-water supplied, taking into account the *Guidelines for Drinking-water Quality* (GDWQ) of the World Health Organization (WHO);
- In accordance with Article 6 Paragraph 5 (c), Parties shall establish and maintain a legal and institutional framework for monitoring and enforcing standards for the quality of drinking-water;
- In accordance with Article 14 (h) Parties shall promote the operation of effective networks to monitor and assess the provision and quality of water-related services, and development of integrated information systems.

The framework for safe drinking-water recommended by the WHO Guidelines for Drinking Water Quality (GDWQ) promotes a risk-based preventive management approach to ensure safety of drinking-water. Drinking-water quality surveillance is one of the core components of this framework and is an essential public health function. To be effective drinking-water quality surveillance needs to be aligned with risk-based principles, including prioritization of monitoring parameters and surveillance efforts based on water safety plan (WSP) outcomes. The European Union (EU), for example, also follows a risk-based approach: in 2015, the EU has introduced a risk-based approach through revision of Annex II of the Drinking Water Directive which allows countries to set monitoring programmes based on local risk assessments.

Supporting countries in building effective systems for surveillance of drinking-water quality is a priority area of work under the Protocol. A regional meeting on effective approaches to drinking-water quality surveillance, held in Oslo in May 2015, recognized the importance and need for applying risk-based approaches in standard-setting and surveillance. It recommended the development of an advocacy document for decision makers to support uptake of risk-based approaches in regulations and practice².

This document has been designed around a set of key principles that underlie the concept of risk-based approaches in drinking-water quality surveillance. The purpose of each principle is explained to provide the context and then its role in risk-based drinking-water quality surveillance is justified. The practical application of each principle is then illustrated by appropriate case studies. Using this clear and concise format the document aims to support decision makers, regulators and national and sub-national public health officials, to better understand and appreciate the added value of risk-based water-quality surveillance and thereby strengthen surveillance systems for better protection of public health. The document will provide a strong rationale for the application of risk-based surveillance approaches, and the prioritization of surveillance efforts considering local hazards and available resources.

¹ http://www.unece.org/?id=2975

² For more details see <u>http://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/water-and-sanitation-in-the-who-european-region-2014-highlights/effective-approaches-to-drinking-water-quality-surveillance</u>

Summary list of proposed principles

The key principles and key messages of the document were formulated based on discussions with the Expert Group on risk-based surveillance of drinking-water quality and the WHO technical programme. The key principles are:

- 1. Risk-based drinking-water quality surveillance is a vital function of the water supplier. It incorporates the principles of Water Safety Plans (WSP) and risk management expressed in the WHO Guidelines for Drinking-Water Quality (4th Edition), the EU Commission Directive 2015/1787, and International Standard BS EN 15975-2.
- 2. Risk-based drinking-water quality surveillance is critical to the protection of public health. It is a responsibility of government to facilitate.
- 3. Risk-based drinking-water quality surveillance builds in-depth knowledge of the water system from catchment to consumer.
- 4. Sanitary inspections are a key element of risk-based drinking-water quality surveillance.
- 5. Risk-based drinking-water quality surveillance is a proactive approach to monitoring and controlling critical risks in the water supply. It directs water quality monitoring towards the most important, relevant parameters for system performance and public health protection. It also justifies derogation from regulated parameters and sampling frequencies
- 6. Water quality monitoring accredits, rather than defines system performance. Monitoring for compliance with standards is an important activity when fitted to the known risks of the water supply system.
- 7. Risk-based drinking-water quality surveillance design tools, including sanitary surveys, partially compensate a lack of dedicated laboratory facilities and can improve overall water quality monitoring efforts where resources are limited.
- 8. Risk-based drinking-water quality surveillance increases the resilience of water supply systems by identifying vulnerabilities and improvement actions.
- 9. Strategies for effective communication at all levels is an integral element of surveillance.

Each of the principles will be explained and justified in the following sections. A uniform template has been used for the discussion of the principles to simplify navigation through the document and cross-referencing. Detailed explanation and rationale for each principle will be provided. The content and scope proposed by the technical experts will be used in the development of the document.

In addition, each principle will include relevant case studies that provide an example of the significance and practical application of the principle. There may be several case studies relevant to one principle. Moreover, one case study may also be relevant to more than one principle.

Supporting documents relevant to a specific principle are referenced at the end of the section; publications that have broader relevance to the theme of risk-based water-quality surveillance are included in Annex XXX.

Explanation of principles

Risk-based drinking-water quality surveillance is a vital function of the water supplier. It incorporates the principles of Water Safety Plans (WSP) and risk management expressed in the WHO Guidelines for Drinking-Water Quality (4th Edition), the EU Commission Directive 2015/1787, and International Standard BS EN 15975-2.

Explanation

Drinking-water can be a vehicle for the transmission of disease, so the provision of safe drinking-water has a vital public health function. Through the provision of drinking-water every supplier assumes the responsibility to protect public health. How best to achieve safe drinking-water has evolved over many years, but it is incumbent upon the supplier to apply current best practice to produce drinking-water to the highest achievable standard. Risk-based drinking-water quality surveillance is accepted best practice within the framework of water safety plans and therefore a vital function of the water supplier.

For most of the 20th Century the quality of drinking-water supply systems was assessed by testing water samples for compliance against an extensive list of parameters. Sampling frequencies, methodology, parameter values and compliance rates were tightly defined in regulations governing water supplies. Provided that the concentrations of parameters were within the specified limits the water was judged to be safe. However, rigid adherence to compliance monitoring as the sole measure of safety has dangerous limitations. Conditions in a water supply system change constantly with impacts on the quality of the water ranging from insignificant to severe. The timescales for these changes can be short or long. In the context of a changing system, water quality monitoring has an unavoidable weakness, namely the samples taken are representative of the quality of the water ONLY at the time they were taken and at the sampling point. Intermittent, detrimental changes in the quality of water being supplied are likely to be missed resulting in an underestimate of the risk to the health of consumers. This can be illustrated using the example of small water supplies. The Private Water Supply (England) Regulations 2016 stipulate that water supplies distributing less than 100 m^3 per day – equivalent to approximately 150 households - be sampled twice a year. If the time taken to take a sample is less than a minute it is inconceivable that the two samples give a true representation of the quality of the water at any other time of the year. No matter how short the interval between sampling events, there is always uncertainty about the quality of the water in the intervening period.

The third edition of the WHO Guidelines for Drinking-water Quality (2004) introduced an alternative to compliance-based monitoring that involves the management of drinking-water supplies using a comprehensive analysis of hazards that might impact a water supply, and an assessment of the risks of the hazards having an impact. This concept was called a Water Safety Plan, and it now forms the core of effective water quality management practices. Water quality monitoring has not been removed from the Guidelines, but the emphasis has been changed: it is now used to verify the successful operation of the water safety plan rather than being the sole indicator of safety. This approach to managing water supplies has been adopted in the EU Drinking Water Directive (which allows member states to "[...] provide for the possibility to derogate from the parameters and sampling frequencies [laid down], provided that a risk assessment is carried out..." (REF)) and is contained in International Standard BS EN 15975-2. A risk-based approach to managing safe water supplies is now accepted best practice and risk-based water quality surveillance is a vital component of this approach.

Justification

Risk-based water quality surveillance can be justified by targeting analytical resources towards the most significant risks, concentrating analysis on the most hazardous contaminants, reduced costs and improved public health. But RBWQS is not an independent activity; it takes place within the framework of an operational water safety plan. The most significant waterborne disease outbreaks have been the motivation behind changes to the management and operation of drinking-water delivery systems (Stein 2000; Hrudey et al. 2003). With few exceptions, the enquiries set up in response to these outbreaks identified operational failures that were compounded by an inadequate response to test results indicating the presence of contamination (for example: Stein 2000). Whether or not a water safety plan was named specifically in the recommendations of the enquiries, all were clear about the need for building an understanding of the risks from catchment through to the consumer, and about managing the risks: the core principles of a water safety plan. Implementation of a water safety plan can bring substantial benefits in terms of increased compliance with national standards, reduced microbial contamination of drinking-water, and a reduction in the incidence of diarrhoeal disease (Gunnarsdottir et al. 2012; Jetoo et al. 2015). (reference from the DWI?).

Water surveillance involves more than just water quality monitoring, it is "...the external and periodic review of all aspects of water quality and public health safety", in which water quality monitoring is an important component (Rickert et al. 2016). (Integrate: WHO – guidelines advocates RBS – why? – surveillance definition (Continuous and vigilant public health assessment and review of the safety and acceptability of drinking water supplies (WHO 1976))). But water quality monitoring is expensive. The cost of equipping, staffing and maintaining analytical laboratories is very high, to which must be added the cost of purchasing and maintaining vehicles to travel to the sample locations. If the individual usefulness of these samples is questionable (summarised in the Explanation) the cost effectiveness of the water quality monitoring programme will be low. This has important implications for the consumer, whose tariff will remain high without a noticeable improvement to the quality of the water and service provision. By concentrating the water quality monitoring programme on the parts of the delivery system at the highest risk of contamination, and testing for the most relevant parameters identified by surveillance activities in the water safety plan, valuable data can be collected without unnecessary expenditure.

Risk-based water quality surveillance protects the health of consumers in the most costeffective way.

Relevant case studies

Summarise and cross reference. To be completed when case studies have been submitted.

Bibliography and further reading

Gunnarsdottir, M.J. et al., 2012. Benefits of Water Safety Plans: Microbiology, Compliance, and Public Health. *Environmental Science and Technology*, 46, pp.7782–7789.

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Jetoo, S., Grover, V.I. & Krantzberg, G., 2015. The toledo drinking water advisory:

Suggested application of the water safety planning approach. *Sustainability*, 7(8), pp.9787–9808.

Rickert, E.B., Barrenberg, E. & Schmoll, O., 2016. TAKING POLICY ACTION TO IMPROVE SMALL-SCALE WATER SUPPLY AND SANITATION SYSTEMS: Tools and good practices from the pan-European region, Copenhagen.

Stein, P.L., 2000. The great Sydney water crisis of 1998. *Water, Air, and Soil Pollution*, 123(1–4), pp.419–436. Available at: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0034302698&partnerID=40&md5=51d197255132dfeec16d04c7e2da7b50.

Risk-based drinking-water quality surveillance is critical to the protection of public health. It is a responsibility of government to facilitate.

Explanation

The capacity for drinking water supply systems to disseminate contamination and cause disease should not be underestimated. According to the WHO (WHO GDWQ 4th Ed), "*Diseases related to contamination of drinking-water constitute a major burden on human health*". Between 2000 and 2014, 68 recorded outbreaks of waterborne disease have occurred as a result of contaminated drinking water supplies (Moreira & Bondelind 2017). Possibly the most widely publicised outbreak was in Walkerton, Canada in 2000, when an estimated 2,300 cases and seven deaths occurred as a result of consumption of a contaminated drinking-water supply (Hrudey et al. 2003). However, the Walkerton outbreak is not the largest that has been reported since 2000. Two outbreaks in Sweden, one in 2010 and one in 2011, affected an estimated 47,000 people (ANDERSSON et al. 2014; Widerström et al. 2014).

Moreira & Bondelind (2017) have categorised the outbreaks according to the reported cause (Figure 1). Failures in the distribution system was the most common cause of disease outbreaks, but the largest number of cases (over 60,000) was attributed to surface water contamination (Moreira & Bondelind 2017).



Figure 1 Number of published outbreaks between 2000 and 2014 categorised by cause (Moreira & Bondelind 2017)

Waterborne outbreaks of disease are still common, and a large number of people are being adversely affected by contaminated water supplies. The WHO (WHO GDWQ 4th ed) states that "*Interventions to improve the quality of drinking-water provide significant health benefits*"; hence, managing water supplies to protect the safety of drinking-water is a vital public health function.

End product testing has traditionally been used to assess whether drinking water is safe to drink. However, as discussed in principle XX it is now considered that relying on routine monitoring of water is ineffective and 'too little, too late'. This is partly because most national standards have been set using faecal indicator bacteria (eg *E. coli*), which indicate faecal contamination in the water supply but not necessarily the presence of pathogens. Instead, monitoring should be used to verify the risk assessment process to ensure that it is working correctly as well as the effectiveness of control measures introduced into the water supply system, and assessing the level of risk from specific sources of contamination (Principle XX). This avoids the need for unnecessary sampling and analysis, whilst maintaining a safe water supply. Indeed, Paragraph (6) in the preamble to the EU Directive

2015/1787 (which amends Annexes II and III to Council Directive 98/83/EC) advocates riskbased water quality surveillance as a means of improving the efficiency and relevance of water quality monitoring: "... for many (particularly physico-chemical) parameters, the concentrations present would rarely result in a breach of limit values. Monitoring and reporting such parameters without practical relevance imply significant costs, especially where large numbers of parameters need to be considered". Collecting data that is of little or no practical value is a waste of resources. The monitoring undertaken as part of the verification process should be consistent with water quality targets set by government (WHO, 2009).

Justification

Waterborne disease continues to impose a significant level of morbidity and mortality on society. Hence, water suppliers are at the forefront of protecting the health of consumers by ensuring that their water supplies are safe. The potential for harm if water supplies fail is immense, as illustrated by the two waterborne disease outbreaks in Sweden (Widerström et al. 2014; ANDERSSON et al. 2014). Risk-based water quality surveillance, set within the framework of a Water Safety Plan, is the most effective mechanism for securing water safety within the available resources of the water supplier. Its implementation is a vital function of the water supplier (Principle XX).

Regulation is inextricably linked with management. This has become more so since 1997 when risk assessments and risk management were introduced. Risk assessments can be considered as a regulatory tool in as much as they deal with all types of hazards, including those that are covered by standards and monitoring, and those that are not. An example of the latter would be an irregular power supply that represents a risk to drinking-water quality, but is not controlled by testing. However a risk assessment would pick this up and give the water company an opportunity to fix it. This would then serve as due diligence if an incident occurred. Ultimately, it is the responsibility of the water supplier to fulfil this function (WHO GDWQ 4th ed and Principle 1), but the supplier requires an appropriate regulatory framework within which to operate and the resources to carry out the work, which are the responsibility of government to provide.

A number of countries' regulations for drinking water quality now specify a requirement for water suppliers to implement a risk assessment and risk management approach (eg a Water Safety Plan) to the production and distribution of drinking water. The level of detail required varies but for regulations requiring implementation of risk assessments/management to be effective it is essential that water suppliers fully understand the approach. The approach towards risk assessment/management should be flexible to ensure that it is successful and it is important that regulations do not become so prescriptive as to prevent water suppliers from developing approaches that work well for them.

The risk assessment/management approach allows the regulator to gain insight into how well the supplier understands and protects the system by looking at the hazard assessment and control measures. Where there is a regulatory requirement the regulator can become the external auditor.

Relevant case studies

To be added.

Bibliography and further reading

ANDERSSON, T. et al., 2014. Syndromic surveillance for local outbreak detection and awareness: evaluating outbreak signals of acute gastroenteritis in telephone triage, web-based queries and over-the-counter pharmacy sales. *Epidemiology and Infection*, 142(2), pp.303–313. Available at:

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Risk-based drinking-water quality surveillance builds in-depth knowledge of the water system from catchment to consumer.

Explanation

Risk-based water quality surveillance sits at the interface between the elements of the water supply system and the water quality monitoring activities. This is represented in Figure 2 where the role of risk-based surveillance is symbolised by the red, dashed, vertical line, with the elements of the water system to the left and the monitoring activities to the right. The figure is not complete because it lacks feedback pathways, but the unidirectional flow is



Figure 2 The interface between water supply, risk-based surveillance, and monitoring response (needs acknowledgement).

Risk-based surveillance drives the purpose of water quality monitoring, as shown in the column on the right of the surveillance activity in Figure 2, but is itself determined by the nature and condition of the water supply system. For example, the type of water source – groundwater or surface water - and the catchment that feeds it will determine the quality of the water. While the potential number of influencing factors in the catchment can be very large, an appropriate assessment of the catchment will identify the most important. Water quality monitoring can then be concentrated on verifying the levels of contaminants and the likely sources of pollution. This information, in turn, decides the most appropriate form(s) of intervention. In this example, risk-based surveillance is being used to target water quality

monitoring at the most pressing problems and avoiding unnecessary use of time and resources.

The same reasoning can be applied to all other components of the water supply system. Thus, by implementing risk-based surveillance at each component of the water supply system, the operator will build an in-depth knowledge of the system.

Justification

Frequently, the operators of small water supplies have a limited knowledge of the systems that they operate and the vulnerability of their systems to contamination. Furthermore, some operators are unaware of the importance of treatment systems and their modes of operation. This lack of knowledge and understanding compounds any natural and technical risks to the system, and leaves the consumers vulnerable to receiving unsafe water supplies. Numerous outbreaks of disease have occurred as a result of this type of complacency (example: Walkerton?).

The process of implementing a water safety plan requires, at an early stage, "A detailed description of the water supply...to support the subsequent risk-assessment process." (WHO water safety plan manual). Following this activity, the water supplier will have a reasonable familiarity with the water supply system. Hazards within the catchment and around the source will be mapped, and vulnerabilities within the water supply systems will have been identified. This information allows the water supplier to evaluate the risks to the system and plan their response in terms of interventions.

Whilst having a detailed description of the water supply is a vital element of managing the system effectively, a deeper level of understanding will emerge from water quality surveillance. The risks identified in the water safety plan will inform the nature and scope of the monitoring activities, but it is the output from the monitoring activities that create a deeper understanding of the water supply system, its performance, and its vulnerabilities to surrounding hazards. As a simple example, the presence of high numbers of heterotrophic bacteria at points in the distribution system may indicate the presence of developing biofilms that can harbour pathogens. This type of information would not be available from mapping the supply system, although it might be implied by the risk assessment.

The safe and effective operation of a water supply system requires a full understanding of the system. This understanding develops with the implementation of a water safety plan and is refined by risk-based water quality surveillance.

Relevant case studies

Bibliography and further reading

Sanitary inspections (SI) are a key component of risk-based drinking-water quality surveillance.

SIs aim to assist engineers, operators, and water and health officers to identify the most important causes and pathways of contamination. The results of SIs can inform control options to prevent or minimize contamination of water supplies. The approach can be applied more broadly to inform regional or national priorities for improving small supplies.

Explanation

Volume 3 of the WHO GDWQ, 1997, describes SI as "on-site inspection and evaluation by qualified individuals of all conditions, devices, and practices in the water-supply system that pose an actual or potential danger to the health and well-being of the consumer. It is a fact-finding activity that should identify system deficiencies—not only sources of actual contamination but also inadequacies and lack of integrity in the system that could lead to contamination "(WHO, 1997).

The Guidelines contain several templates for the inspection of different types of water supply systems. In general, the forms consist of 10 to 12 questions about the potential sources of contamination and the pathways by which the contaminants can reach the water supply. The questions are written in such a way that an answer of "yes" indicates a risk resulting from the source or pathway. The more questions that are answered "yes" the higher the risk. (Reference) have compiled the percentage risks into bands that provide guidance as to the significance of the risk. A further dimension can be added by including the results of microbiological tests to create a matrix that highlights priorities for interventions (reference). The specific functions of the sanitary inspections report, as set out in WHO (1997), are to:

- identify potential sources and points of contamination of the water supply;
- quantify the hazard (hazard score) attributable to the sources and supply;
- provide a clear, graphical means of explaining the hazards to the operator/user;
- provide clear guidance as to the remedial action required to protect and improve the supply;

- provide the raw data for use in systematic, strategic planning for improvement. Water professionals have debated the value of SIs for many years with some arguing that they are unreliable at predicting faecal contamination as measured by the presence of thermotolerant (faecal) coliform bacteria, including *E.coli*. They point to the frequent absence of a correlation between sanitary risk score and density of faecal indicator bacteria; in particular high risk sources that have a low level of contamination. But this argument misses the point of SI, which is to measure the level of risk at the source and the potential for contamination. Whether or not contamination is present in the source can involve factors that are not considered as part of the SI and are not present at the time of the inspection. What is important is that the risks that are identified by the SI are properly assessed and dealt with. Sanitary inspections form an integral part of a Water Safety Plan.

Justification

Small water supplies are widespread and pose a health-risk to users if not managed properly. Reports of outbreaks in Canada and the United States, for example, indicate that approximately 50% of all waterborne diseases occur in small, non-community drinking water systems (Pons et al., 2015). These types of supplies are often managed by communities or individuals, and are not supported financially, technically or politically in the same way as large utility-managed supplies. The costs associated with monitoring and management of water supplies are high, and therefore a robust low-cost risk assessment is invaluable for small supplies. Sanitary inspections provide an option to assess the catchment and water supply and identify the most important causes and pathways of contamination (even when there is no evidence of microbiological or chemical contamination). This information allows control options to be designed to prevent or minimize contamination to the supply. More specifically, the process of risk assessment is a systematic evaluation of:

1) hazards - e.g. pathogens that may have an adverse impact on the health of the people who drink the water;

2) hazardous events - e.g. rainfall - events that may introduce pathogens into the water supply or fail to remove them;

3) the adequacy of the controls to prevent contamination – e.g. engineered controls, such as water treatment, or non-engineered measures, such as hygiene protocols for repair works on the water distribution.

Sanitary surveying has many advantages over water quality monitoring:

- It is cheap, requires neither equipment nor highly-skilled staff, and may easily be performed regularly or routinely.
- It can reveal conditions or practices that may cause isolated pollution incidents or longer-term pollution.
- It reveals the most obvious possible sources of contamination, but may not reveal all sources of contamination, for example, remote contamination of groundwater.

Relevant case studies

Bibliography and further reading

Pons W., Young, I., Truong, J., Jones-Bitton, A., McEwen, S., Pintar, K., Papadopoulos, A. (2015). A Systematic Review of Waterborne Disease Outbreaks Associated with Small Non-Community Drinking Water Systems in Canada and the United States. PLOS One 10(10): e0141646. <u>https://doi.org/10.1371/journal.pone.0141646</u>. WHO (1997)

Water quality monitoring accredits, rather than defines system performance. *This principle will incorporate the explanation of "too little, too late", and that end-product testing fails to provide significant public health protection. It will also include the different roles of WQ monitoring.*

Explanation

One of the primary concerns of water suppliers is to ensure that the drinking water they supply does not pose an unacceptable risk to the health of consumers. To achieve this, suppliers refer to national standards or international guidelines that define the admissible concentrations of a range of biological, chemical and physical parameters. Alternatively, or in parallel with the comprehensive monitoring programme, indicators of water quality (such as turbidity) can be measured to assess the potential presence of broad groups of parameters (Stevens et al., 2003). If the water does not breach the admissible concentrations, or is free of indicators, water suppliers consider that the water is safe. In these circumstances, water quality monitoring is being used to define the performance of the water supply system. The regulatory framework that drives the activities of water suppliers frequently defines the number of samples taken and the frequency of sampling. The WHO GDWQ (REF) and the EU Drinking-Water Directive (REF), for example, recommend increasing the sampling frequency and the number of samples as the population supplied increases. For large water supplies under the control of water authorities, sample numbers are large, and the frequency of sampling is high. But at the opposite end of the scale populated by small water supplies, the number of samples can be small – often a single sample – and the frequency of sampling extremely low – often once every few years. (Provide an example). In the interval between sampling events the quality of the water is unknown.

Water quality and treatment processes are often affected by seasonal changes or sudden operational shifts, such as a pipe break or flooding. By testing at intervals defined by regulations, such as seasonal sampling, intervening events can be missed. This is illustrated in Figure 3.



Figure 3 Seasonal changes in turbidity of a surface water source.

Another level of uncertainty occurs in the interval between the time the sample was taken and when the analytical results are returned to the water supplier. The time between taking the sample and receipt of the analytical result varies due to several factors, including the time it takes to carry out the test. For some chemical parameters analysis can be quite quick (less than one hour), but others can take longer. Of greater concern is the time taken to complete the tests for microbial parameters, which can be up to 48 hours for the routine indicators of faecal contamination. The implications of this delay are profound: by the time contamination has been identified, consumers will have been exposed to the contaminant and may already be displaying signs of illness. Hence, monitoring in this context represents a retrospective check of quality, rather than a proactive demonstration of safety.

In addition to the limitations imposed by rigid sampling regimes, making judgements from the presence or absence of certain parameters is not straightforward. The GDWQ prioritize the microbial safety of water, due to the immediate and potentially widespread consequences of pathogens being present in the supply. The pathogens that have been of greatest concern in drinking-water are those excreted in faeces, and are transmitted by the faecal-oral route. This group of pathogens includes microorganisms from all families: the bacteria, viruses, and protozoa. Standard, routine methods for testing the microbial safety of water use a group of bacteria that are ubiquitous in faeces, but in themselves are not pathogens; namely, the coliform group of bacteria (which includes *E.coli*) and the enterococci. Their purpose is to indicate the presence of faecal contamination, and therefore the risk that pathogens may be present in the water. The strength of the indicator concept lies in the wealth of information that has been accumulated during the 100 years that they have been used in the water industry. The coliform group of indicator bacteria originally was introduced for the specific purpose of being a surrogate for the typhoid bacillus, which was a significant cause of waterrelated disease. In this role, the coliform group of bacteria performed well as an indicator because their characteristics and those of the pathogen are very similar. An equivalent similarity does not exist between the coliform group of bacteria and pathogens of the protozoa and virus groups. Here, the absence of indicator bacteria - the normal measure of safety of a water supply – is not a guarantee of the absence of viral or protozoal pathogens, which have very different survival characteristics and susceptibility to methods of water treatment. Many authors have questioned the relevance of coliforms as an indicator of water safety, and point to the absence of any correlation between the presence or absence of coliform bacteria and health risk. However, there are currently no more robust alternatives, and the routine testing for coliform bacteria, now more specifically *E.coli*, continues to be the dominant microbial test.

Water quality surveillance driven solely by the imperative to demonstrate compliance with parameter values will always be at the mercy of unforeseen circumstances resulting from fluctuating concentrations of parameters. A sample can only represent the quality of the water at the time and location the sample was taken. The quality of the water before and after the sample was taken can only be assumed. Given the long interval between sampling events for small water supplies, the sampling frequency is *too little* to be effective. Furthermore, the time taken for analytical results to be returned to the water supplier can result in consumers being exposed to the contamination before the contamination has been recognised. Analytical results are often received *too late* to protect public health.

Traditional approaches to water quality surveillance are an unreliable indicator of system performance. This is illustrated by several examples of major outbreaks of diseases, such as infectious hepatitis, where the bacteriological samples complied with legislative requirements. In the USA between 1978 and 1986 there were 502 reported outbreaks of waterborne disease involving more than 110 000 cases of gastrointestinal illness. Many of the

implicated water supplies in these outbreaks met the coliform compliance requirements of the USEPA (Sobsey, 1989).

Justification

Water quality monitoring refers to the sampling and analysis of water constituents and conditions. It is a measure of the physical, chemical, biological characteristics of water, which can provide practical evidence to support decision-making on health and environmental issues. The main reasons for monitoring drinking-water quality are:

- to determine if the water supply system is being operated correctly, implying that the water is safe for consumers; and
- to provide proof that the water was safe after it was supplied. This includes monitoring for compliance.
- to alert us to current, ongoing, and emerging problems; to determine compliance with drinking water standards,
- to protect other beneficial uses of water.
- Assessments based on monitoring data help to measure effectiveness of water policies, determine if water quality is getting better or worse, and formulate new policies to better protect human health and the environment. https://water.usgs.gov/owq/WhyMonitorWaterQuality.pdf

Yet used in isolation, *water quality monitoring provides too little information too late*. Therefore, as the sole method for defining the performance and safety of a water supply system, water quality monitoring is flawed. It is only when monitoring is integrated into a comprehensive risk-based surveillance programme that its value is fully realised. Water safety plans shift the emphasis away from water quality monitoring to risk assessment and risk management as a mechanism for ensuring the safety of water supplies. Within the framework of a water safety plan, water quality monitoring assumes a more valuable and cost-effective role. Risk assessments can target monitoring towards vulnerable parts of the supply system, as well as define the most appropriate parameters. This avoids taking unnecessary samples and testing for unnecessary parameters. Monitoring can also be implemented to confirm the efficacy of a control measure that has been incorporated into the supply system to mitigate the impact of a system failure or an identified risk. Once again, the defined purpose of the monitoring programme avoids wasting valuable resources. In these circumstances the role of water quality monitoring is being used to accredit, rather than define, the performance of the water supply system.

Relevant case studies

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Sobsey, 1989 Taylor

Risk-based surveillance increases the resilience of water supply systems

Explanation

The sustainable availability of safe drinking-water will be at risk unless water supply systems are resilient to both current levels of climatic variability and future change. Higher incidence of flooding or drought, will result in adverse impacts on water supply services through damage to infrastructure, loss of water resources and changes in quality of water, posing a danger to development and human health (Howard et al., 2016). Population growth, urbanization and expanded industrial activities will also result in increases in water demand and exacerbate the impacts of climate change.

Risk-based surveillance supports both strategic and operational decision making. Drinking water technologies are potentially vulnerable to climate and environmental changes. Adaptive risk management systems such as Water Safety Plans can effectively assess and manage risks posed by climate change (Bartram et al. 2009).

The World Health Organization (WHO) Guidelines for drinking-water quality (WHO,) recommends water safety planning, and the WHO/International Water Association (IWA) Water safety plan manual (2) notes: *There can be a tendency for the identification of hazards to be limited to thinking about those direct inputs to the water supply system impacting microbial and chemical parameters, as these are important in terms of compliance with water quality standards. However, the approach to ensure safe water must go much wider, with consideration of aspects such as potential for flood damage, sufficiency of source water and alternative supplies, availability and reliability of power supplies, the quality of treatment chemicals and materials, training programmes, the availability of trained staff, service reservoir cleaning, knowledge of the distribution system, security, emergency procedures, reliability of communication systems and availability of laboratory facilities all requiring risk assessment.*

Prioritising the development of risk-based surveillance programmes is likely to be critical to promoting more effective and resilient water supplies, but will require the development of new tools to support climate adaptation. This would facilitate local level assessments that ultimately will be required to help build resilience and identify adaptations (Howard et al., 2010).

The principles and practice of water safety planning, requires risks to drinking-water safety and security to be identified, prioritized and managed before problems occur. It is therefore a useful tool to address the impacts of climate change.

Justification

Globally, water-related disasters already account for 90% of all natural disasters (WWDR4, 2012). Due to climate change their frequency and intensity is rising. Damages attributed to water-related disasters can be up to 15% of annual GDP for certain countries (Vlaanderen, 2015).

Population growth, poverty, land shortages, urbanization, the poor condition of flood protection and drainage infrastructure, and water storage facilities, have increased the vulnerability of people to extreme weather events and, multiplied impacts on public health associated with water-borne epidemics. Climate change models predict decreases of renewable water resources in some regions and increases in others, with large uncertainty in many places (4).

Risk reduction, preparation and prevention are sensible investments that pay off in terms of reduced loss of life, avoided damage, and long-term economic growth and stability.

Preventive action aims at developing measures to increase the resilience to cope with potentially disastrous events.

Those responsible for drinking-water safety need to have a good understanding of how climate change is affecting water resources and thus drinking-water supply systems to inform changes to policies, programmes and infrastructure to prepare for and cope with changing freshwater quantity and quality (WHO,). Adapting the water safety plan approach in order to incorporate the expertise of climatologists to help predict the conditions under which a water system may need to cope will help to increase the adaption and resilience of water supply systems to climate change. L With climate change in mind, the WSP team should consider the types of hazards that might become more problematic within the local context with reference to general checklists of hazards, hazardous events and control measures. Long-term planning for continuing access to freshwater sources; managing water demand among competing needs; reviewing the resilience of the supply system itself; addressing policy needs, such as for water storage and flood control; implementation of control measures to ensure water quality (and quantity) is required. The WSP process provides an effective framework to systematically address many of these requirements (WHO, 2017).

Relevant case studies

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Strategies for effective communication at all levels is an integral element of surveillance.

Explanation

Effective communication requires conveying or transmitting information between parties. Interested parties include government, agencies, corporations and industry groups, unions, the media, scientists, professional organisations, interested groups, and individual citizens (Covello et al. 1991). Its goal can vary. Communication can be used simply to share information, or to change people's belief or change behaviour. To be adequate, communications must contain the information that users need, connect users with that information, and be understood by users (Fischhof, 2011).

It is vital to have an effective communication and coordination strategy, to report results back to stakeholders and is particularly important when investigating a possible drinking water contamination incident, to mitigate significant public health and economic consequences. As detailed in the WHO Guidelines for Drinking-water Quality (2017), proper reporting and feedback will support the development of effective remedial strategies. The ability of the surveillance programme to identify and advocate interventions to improve water supply is highly dependent on the ability to analyse and present information in a meaningful way to different target audiences.

Communication strategies should include (list not exhaustive):

- Adequate training of staff to ensure that all members of the surveillance team are familiar and understand the significance of day-to-day activities as well as what to do in an emergency situation. Staff must be trained in and understand the significance of their roles.
- Reporting results and the significance of the results of monitoring activities to relevant stakeholders.
- Summary information to be made available to consumers for example, through annual reports and on the Internet;
- Procedures for rapidly advising stakeholders of any significant incidents within the drinking-water supply, including notification of the public health authority. This may be through the media or face-to face;
- Liaison with communities, suppliers media and regional authorities;
- Establishment of mechanisms to receive and actively address community complaints in a timely fashion.

It may be appropriate to use community organizations such as local councils and communitybased organizations, such as women's groups, religious groups and schools to provide a mechanism of relaying important information to a large number of people within the community. Furthermore, by using local organizations, it is often easier to initiate a process of discussion and decision-making within the community concerning water quality. The most important element in working with local organizations is to ensure that the organization selected can access the whole community and can initiate discussion on the results of surveillance (WHO, 2017).

If communication is not effective both within surveillance agencies and between the agencies and users, then there is danger of serious public health impacts and loss of consumer confidence. There is evidence of this occurring on numerous occasions (see case studies below).

Justification

An essential part of a surveillance programme is the reporting of results to stakeholders. This will support the development of effective mitigation and intervention strategies. Stakeholders may include public health officials, local administrations, communities and water users, local regional and national authorities responsible for development planning and investment. Effective communication helps to increase awareness and knowledge of drinking-water issues and areas of responsibilities. This helps consumers to understand and contribute to decisions about the service provided by a drinking-water supplier or land-use constraints in a catchment. In addition, effective communication by consumers allows their expectations to be met.

As well as day-to-day running of water utilities, communication forms a key component of emergency plans which should be developed by water suppliers. These plans should consider potential natural disasters (e.g., earthquakes, floods, damage to electrical equipment by lightning strikes), accidents (e.g., spills in the watershed), damage to treatment plant and distribution system and human actions (e.g., strikes, sabotage). Emergency plans should clearly specify responsibilities for coordinating measures to be taken, a communication plan to alert and inform users of the drinking-water supply and plans for providing and distributing emergency supplies of drinking-water (WHO, 2004).

Relevant case studies

To be added.

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Case studies

Title: Rapid assessment of drinking water quality and prevailing sanitary conditions in small-scale	
water supply systems in rural areas in Serbia	

Case study number:	Location: The Republic of Serbia
CS1	

Relevant principle: Risk-based drinking-water quality surveillance is a proactive approach to monitoring and controlling critical risks in the water supply. It directs water quality monitoring towards the most important, relevant parameters for system performance and public health protection. It also justifies derogation from regulated parameters and sampling frequencies or

Risk-based drinking-water quality surveillance design tools, including sanitary surveys, partially compensate a lack of dedicated laboratory facilities and can improve overall water quality monitoring efforts where resources are limited.

Background to the case study:

Drinking-water quality monitoring in rural areas in Serbia is an integral part of the national "Programme on the Protection of the Population Against Infectious Diseases". It is being conducted by the network of the institutes of public health under the Ministry of Health. The drinking water quality parameters and sampling frequency are regulated by the Rule on Hygienic Correctness of Drinking-water ("Official Gazette of SRJ", no. 42/98) for the water supplies that serve more than 20 people (or 5 households). However, the enforcement is weak in rural areas, which resulted in a lack of data on water quality and prevailing sanitary conditions in small-scale water supply systems (SSWSs). Existing challenges such as unregulated ownership of the numbers of rural small water supplies, the lack of responsibility for maintenance and monitoring of facilities, as well as for testing the quality of drinking water hamper the drinking-water quality surveillance.

Absence of a legal entity in managing these water supply systems prevents operation of the sanitary inspection. Maintenance is not supported by the necessary attention, double connections in some households and various illegal connections increase the risk of water contamination, which pose potential risk to health of rural population.

The Republic of Serbia has used the target setting framework under the Protocol on Water and Health to address SSWSs challenges and close the knowledge gaps risk-based drinking-water quality monitoring. Serbia's national targets set under the Protocol include a specific target on undertaking a systematic assessment of drinking-water quality and prevailing conditions in rural water supplies in order to improve the evidence base on rural water supply and enable informed decision-making.

Description of case study:

A national-level systematic survey was conducted in rural areas of Serbia in 2016 based on a rapid assessment methodology developed by WHO. Two types of water supply technologies were investigated: (i) small piped systems serving up to 10 000 people; and (ii) individual supplies which, according to national standards, comprise systems serving less than five households or 20 inhabitants. In total, 1318 small-scale water supply systems were inspected (1136 piped systems and 182 individual supplies) and 1350 drinking-water samples were taken and analyzed for one microbiological parameter (i.e. *Escherichia coli* – *E.coli*) and 10 physico-chemical parameters (i.e. ammonia, arsenic, chlorine residual, colour, electrical conductivity, hydrogen ions – pH, manganese, nitrate, odour and turbidity). The survey findings clearly show a significant water-quality gap between urban and rural areas (Fig.1).



Fig. 1. Microbial and physico-chemical compliance with national water quality standards in rural and urban water supplies in Serbia

One third of all water samples taken from SSWSs in rural areas were found to be microbiologically contaminated, correlating with identified sanitary risks and unsolved ownership of the large number of small-scale water supply systems. The dominant sanitary risks revealed by sanitary inspection were: absence of regular chlorination, non-established and unmanaged sanitary protection zones, sources of pollution (latrines, sewers, animal breeding, cultivation, roads, industry, rubbish and other sources) placed nearby and unsatisfactory technical conditions.

Lessons learned:

- Rapid assessment methodology enabled the identification of the most important causes of contamination and prioritization for the improvement. It served the public health authorities to identify systems that required increased attention and guidance.
- This survey has helped the public health institutes to establish systematic baseline information on small-scale systems in their area of responsibility, increase attention to the challenges related to such systems, and leverage local action towards their improvement.
- It provided useful baseline information on drinking water quality in local or national context, that can be utilized for national target setting and revising or for prioritizing surveillance efforts.
- In the absence of national inventory of small-scale systems in rural areas, the data obtained through the rapid assessment, including development of study design, can complement the national data needed for investment and financial planning the implementation of Water Framework Directive, particularly EU Drinking Water Directive.
- The survey has induced policy actions and measures for the improvement of rural water supplies. These are directed at amendment and enforcement of existing legislation and programmes, as well as development of new regulations.
- The survey makes a strong contribution for designing further education programmes in hygiene and sanitation.

Recommendations:

The survey results point to the need for: (i) integration of the Water Safety Planning (WSP) approach in a regulation and its implementation to ensure safe drinking water from source to tap; (ii) increased

enforcement of the regulation on foundation and ownership of water supply systems; (iii) development of national and local action plans for improving small-scale systems serving rural populations, and (iv) establishment of a national inventory of small-scale systems that would provide a systematic overview of water supplies in rural areas and effectively support programming of improvement interventions.

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Title: Incorporation of the risk-based surveillance into legislation - example of the European Drinking Water Directive

Case study number:	Location:
CS2	European Union

Relevant principle:

Risk-based water quality surveillance incorporates the principles of surveillance and risk management expressed in the WHO Guidelines for Drinking-Water Quality (4th Edition), the EU Commission Directive 2015/1787, and International Standard BS EN 15975-2.

Background to the case study:

The EU Commission Directive 2015/1787 amended the Annexes II and III of the EU Drinking Water Directive 98/83/EC. Annex II lays down the requirement of drinking water quality monitoring, including parameters to be monitored, monitoring frequency, and the point of sampling. The amendment replaced the previous rigid monitoring scheme by a more flexible, risk-based monitoring programme.



Description of case study:

The amendment requires the EU member states to develop monitoring programmes to ensure that the delivered water is safe and meets the quality requirements laid down in Annex I of DWD. The monitoring programmes do not rely solely on end product testing, but may also include elements of operational monitoring and sanitary inspections (Fig. 1). The minimum frequency of water testing is set based on the volume of supplied water. Basic bacterial indicators, organoleptic properties and a limited number of other parameters (depending on the applied water treatment or the outcome of the risk assessment) are monitored with high frequency, while the "long list parameters" only with a lower frequency (Fig. 2). Sample numbers may be reduced further (even to zero) for those parameters which were not detected in previous measurements, or only present in low concentration, and the risk assessment indicates that the breach of compliance is unlikely. Though the point of compliance is the consumers' tap, samples may be taken at other points in the water supply system if it is demonstrated to be equivalent.

Lessons learned: The incorporation of important elements of risk-based approach into the EU drinking water directive can accelerate the uptake of risk-based supply operation as well as risk-based surveillance in the member states.

Recommendations: Transition from end-product testing to risk-based surveillance should be gradual. Basic water quality testing should be maintained (simple, cost-effective measurements of high indicative value), while the frequency and scope of more sophisticated analysis should be determined by risk assessment.

References

EU Commission Directive 2015/1787 amending the 98/83/EC directive

Title:

Early warning systems in outbreak prevention – case example of a drinking water outbreak in Miskolc following an extreme precipitation event

Case study number:	Location:
CS3	Miskolc, Hungary

Relevant principle:

Risk-based surveillance increases the resilience of water supply systems.

Background to the case study:

Miskolc is a city of approximately 80000 inhabitants located in North-Eastern Hungary. It relies on karstic water for its drinking water supply. Following an extreme precipitation event, it experienced a multi-etiological drinking water outbreak affecting over 3500 people.



Description of case study:

The water of the karstic spring is generally delivered without treatment, except for safety chlorination. The water supply was monitored regularly according to the frequency defined in the drinking water legislation. Samples were tested routinely for turbidity, microbiological and chemical parameters. During a week of extreme precipitation, increased turbidity was observed, but as fecal indicators were not detected, normal operation was continued. Following the 3-day Pentecost holiday, the water supply was resampled, but by the time the results arrived (two days later), general practitioners already reported increased incidence of gastrointestinal illness. Boil water advice was given and the consumption of water restricted. The advice was upheld until the operation of the water supply returned to normal, and the whole system was disinfected. Epidemiological investigation confirmed the consumption of tap water as the source of infection.

Lessons learned:

The cause of the outbreak was the extreme precipitation that changed the underground current in the karst and washed contamination into the water source. Routine testing for fecal indicators was insufficient in preventing the outbreak. Turbidity was found to be indicative of events leading to the deterioration of water quality. Online turbidity monitors were installed, and a control value was assigned to the measurements as an early warning of potential contaminations. A rapid method for *E. coli* testing was also introduced.

Recommendations:

Supply operators should introduce simple operational control points for early detection and water incidents and appropriate interventions.

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